REVIEW OF GROUNDWATER MODELING AND HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT OF THE SOUTHEAST REGION GROUNDWATER OPERABLE UNIT, MASSACHUSETTS MILITARY RESERVATION, CAPE COD, MASSACHUSETTS

REMEDIAL INVESTIGATION REPORT

Prepared for

ASHUMET JOHN'S POND TAG COALITION COMMITTEE (AJPTCC)

Prepared by

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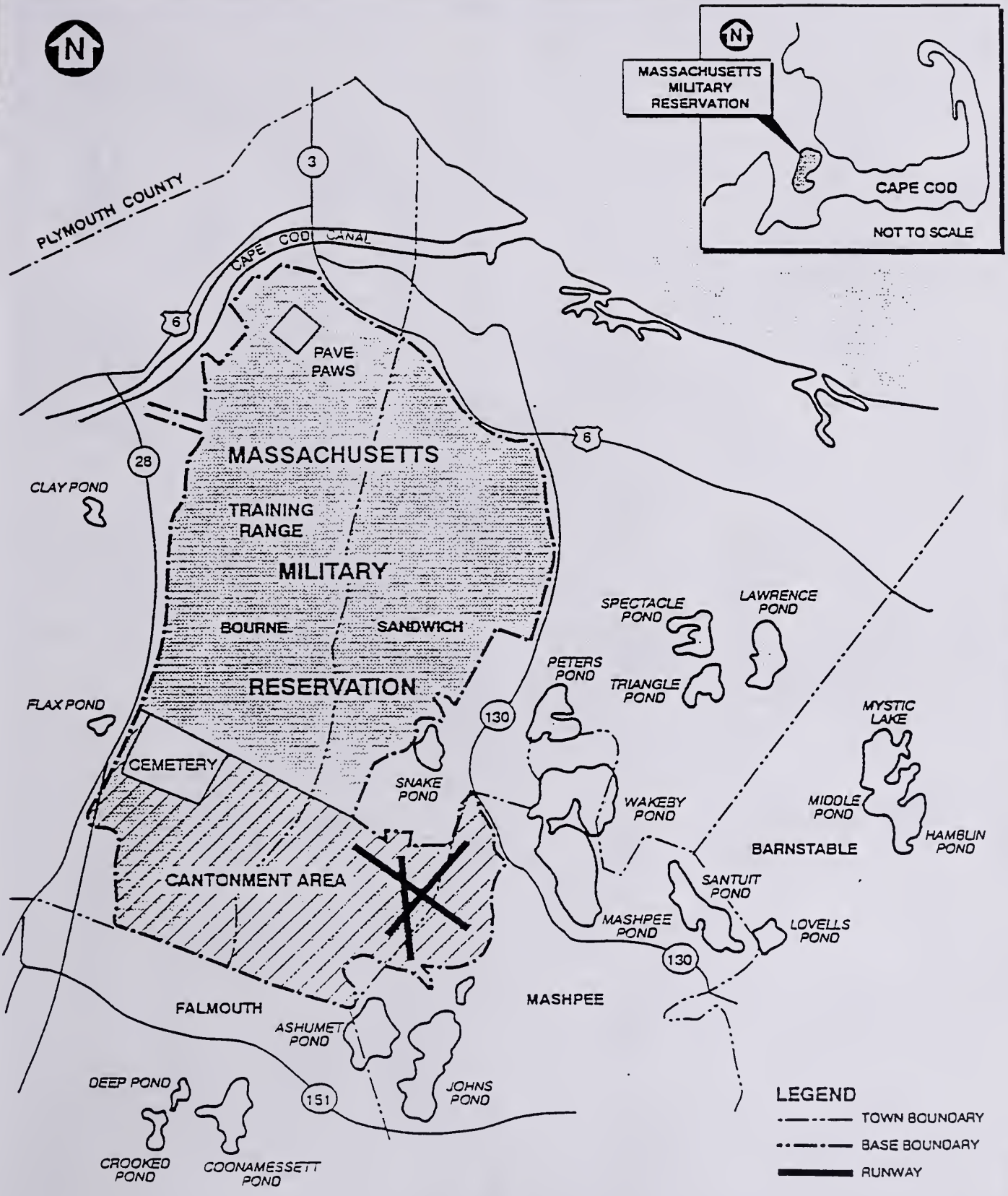
SUMMARY

The purpose of this review is to assess the methods and conclusions reached by ABB (1994) in its evaluation of groundwater transport, human health risk and ecological risk associated with the Southeast Region Groundwater Operable Unit (SERGOU) of the Massachusetts Military Reservation (MMR). SERGOU is the name given to the groundwater in the southeast area of the MMR. Maps of the MMR and SERGOU are presented as Figure 1-1 and Figure 1-2, respectively, copied from ABB (1994).

As described in the Remedial Investigation (ABB, 1994), industrial and military activities in the southeast portion of the MMR have released organic and inorganic contaminants to groundwater. The SERGOU is the largest industrialized portion of the MMR. Primary source areas include sump and storage tanks, fuel storage tanks and pump houses, and a fire training area. Since these sources of contaminants were close together, the groundwater in this area was grouped into one operable unit, the SERGOU. The term operable unit is used for a grouping of contaminant sources with common characteristics, such as location, potential remediation technique, and type of contaminants.

The contaminant plumes in groundwater are shown in Figure 1-3 copied from ASG (1994). This figure shows the general pattern of southerly flow of contaminated groundwater from the SERGOU toward Ashumet and John's Ponds. The on-site contaminants related to operations on the MMR include petroleum products, deicers, solvents, and fuel additives such as ethylene dibromide. These primary contaminants are not detected in off-site surface water and sediment in Ashumet Pond and John's Pond. However, inorganic compounds such as iron, manganese, and arsenic have become elevated in groundwater because of low oxygen conditions caused by biodegradation of site-related organic materials in the groundwater. These minerals are normally present in soil but have very low solubility in water as long as there is oxygen present. Depletion of oxygen results in increased solubility of these minerals. As a result, the groundwater plumes moving toward the ponds contain elevated mineral concentrations and transport some of these minerals to surface water and sediments. Most of the dissolved minerals will re-precipitate as the groundwater nears surface soil or sediment. The most obvious example of this phenomenon is the precipitation of



NOT TO SCALE

ABB Environmental Services, Inc.		SITE LOCATION MAP
INSTALLATION RESTORATION PROGRAM MASSACHUSETTS MILITARY RESERVATION	SERGOU RI	FIGURE 1-1

N94060100(8)

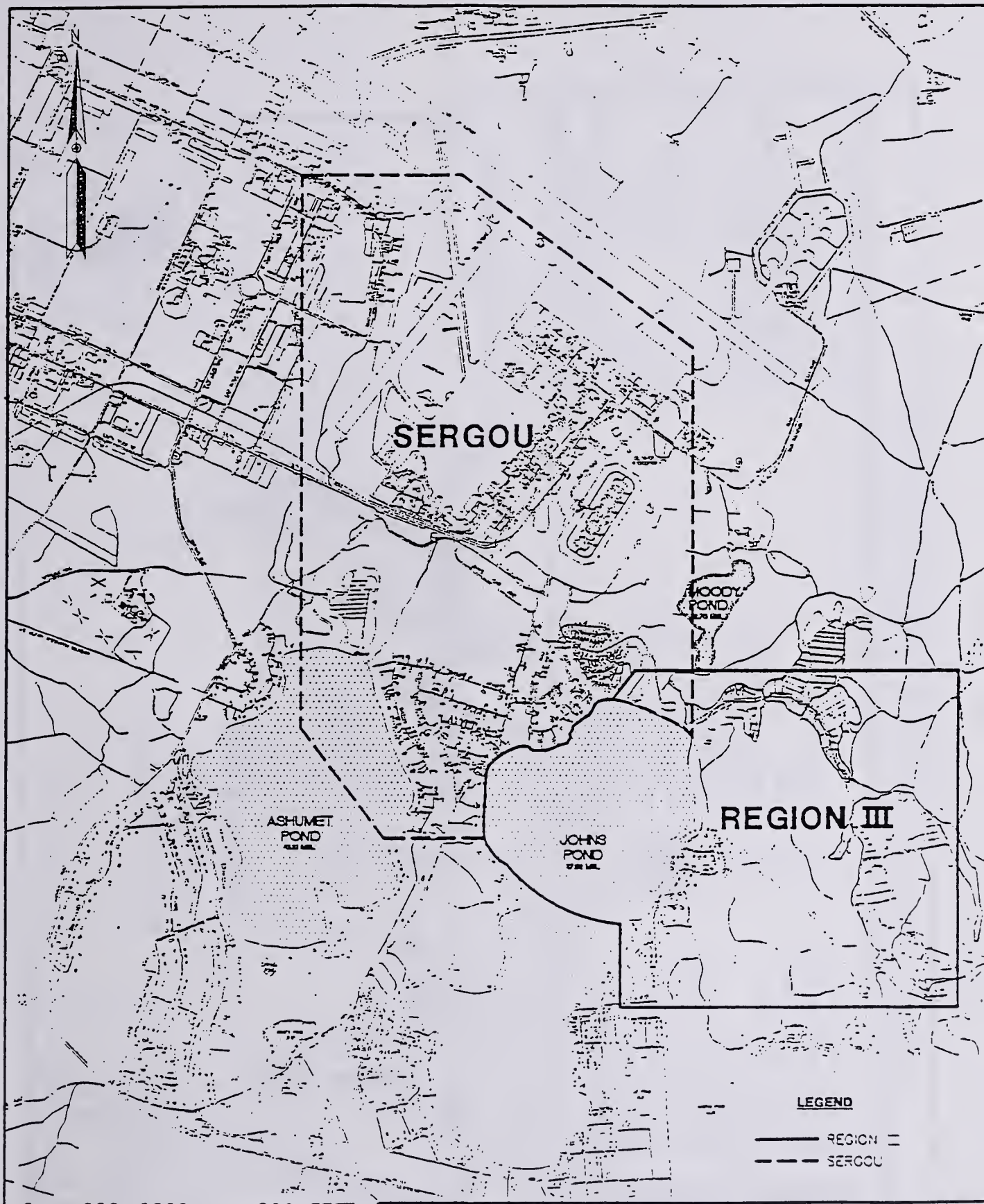

N
SERGOU
WOODY POND
ASHUMET POND
JOHNS POND
REGION III
LEGEND
REGION III
SERGOU
0 1000 2000 4000 FEET
SCALE 1" =2000'
ABB Environmental Services Inc.
SERGOU AND REGION III AREAS OF INVESTIGATION
INSTALLATION RESTORATION PROGRAM
MASSACHUSETTS MILITARY RESERVATION
SERGOU RI
FIGURE 1-2

Figure 1-3. MMR study areas and groundwater plumes map.

manganese on rocks in Fishermen's Cove of Ashumet Pond. The Ashumet Valley groundwater plume enters Ashumet Pond in this area.

The purpose of human health risk assessment is to estimate the probability of human health impacts under realistic exposure conditions to chemicals. All chemicals have some level of risk, depending on the toxicity of the chemical and the level of exposure to that chemical in the food, water, and air. For cancer-causing chemicals, risk is expressed as the cancer probability (e.g. 1 in 1 million). For other health effects, the risk is expressed as a "hazard quotient" which is the estimated dose divided by the "safe" dose. Under most regulations, risks are considered to be acceptable is they do not exceed a cancer risk of 1 in 100,000 or a hazard quotient of 1.

Ecological risk assessment is based on similar principles as human health risk assessment, except that impacts are assessed for non-human species. The techniques are similar, but the impacts to be assessed are generally limited to survival and reproduction, rather than cancer. The primary concerns are ecological impacts to populations of organisms, rather than individuals (unless they are endangered species).

The conclusions of this review were in substantial agreement with the conclusions of the ABB (1994) report. The main conclusions and our recommendations are presented below:

1) Primary contaminants associated with the site (fuels, additives, deicers, solvents) are generally not detected in surface water off the site. However, inorganic minerals such as iron, zinc, manganese, and arsenic are elevated in groundwater due to biodegradation (and related oxygen consumption) of the primary contaminants. These elevated concentrations of dissolved minerals are being transported to the surface waters.

2) Since contaminants in groundwater in the SERGOU area exceed EPA and Massachusetts standards and guidelines, it is unsafe for people to use groundwater from wells in the SERGOU area. This conclusion is supported by the results of the risk assessment.

3) Swimming in Ashumet Pond and John's Pond is safe, even if some water is accidentally ingested during swimming. Dermal contact with water and sediments should not pose a significant health risk.

4) Although manganese is higher than normal in Ashumet Pond surface water, swimming should not have a significant health risk. However, use of Ashumet Pond as a source of drinking water is not recommended at this time, pending EPA's reassessment of manganese toxicity.

5) Regular consumption of fish from Ashumet Pond may be unsafe, based on the detection of arsenic in one of four fish analyzed. Occasionally eating fish from Ashumet Pond is probably safe. Additional fish should be analyzed to determine a more accurate level of arsenic in fish. The source of arsenic is unknown but is probably related to the SERGOU plume, which contains elevated arsenic levels.

6) It is safe to eat fish from John's Pond. Neither arsenic nor other toxic chemicals were detected at significant concentrations in fish from this pond.

7) The measured concentrations of inorganics in surface water were below toxic levels for aquatic organisms in the water column. However, toxicity modeling of inorganics in sediments indicated that toxic effects may be occurring in bottom-dwelling aquatic organisms in both ponds. In the absence of further studies (such as bioassays or pore water measurement), it is concluded that the sediments are probably toxic to aquatic organisms.

8) Some of the inorganics transported to the pond surface water and sediment may pose an unacceptable ecological risk to wildlife such as osprey, mallard ducks and muskrat. This risk is based on conservative modeling of the transfer of these inorganics via food (fish and vegetation) to these organisms. However, a comparison of modeled versus actual concentrations of manganese measured in pond fish suggests that the food chain model may overestimate risk by two to four orders of magnitude (by a factor of hundreds to tens of thousands). Additional analysis of fish tissues is needed to obtain a more realistic estimate of ecological risk via the pond food chain.

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1.0 INTRODUCTION

This report describes the results of a critical review of the Southeast Region Groundwater Operable Unit Remedial Investigation Report (Including Region III) Massachusetts Military Reservation, Cape Cod, Massachusetts Remedial Investigation (ABB, 1994). The Southeast Region Groundwater Operable Unit (SERGOU) is the name given to the southeast area of the Massachusetts Military Reservation (MMR). Maps of the MMR and SERGOU are presented as Figure 1-1 and Figure 1-2, respectively, copied from ABB, 1994.

As described in the Remedial Investigation (ABB, 1994), industrial and military activities in the southeast portion of the MMR have released organic and inorganic contaminants to groundwater. The SERGOU is the largest industrialized portion of the MMR. Primary source areas include sump and storage tanks, fuel storage tanks and pump houses, and a fire training area. Since these sources of contaminants were close together, the groundwater in this area was grouped into one operable unit, the SERGOU. The term operable unit is used for a grouping of contaminant sources with common characteristics, such as location, potential remediation technique, and type of contaminants.

The contaminant plumes in groundwater are shown in Figure 1-3 copied from ASG (1994). This figure shows the general pattern of southerly flow of contaminated groundwater from the SERGOU to Ashumet and Johns Ponds.

The scope of the review is limited to an overall assessment of the Remedial Investigation (RI) with specific emphasis placed on evaluation of the groundwater modeling and human health and ecological risk assessment. In support of this assessment, a review was conducted on the appropriateness and completeness of Applicable or Relevant and Appropriate Requirements (ARARs), contaminant data (useability, representativeness), and conformance with accepted methods for groundwater modeling and risk assessment. The report is organized to provide a general evaluation of each component followed by specific examples of suggested improvements, if any.

A summary of the human health and ecological risk assessment is provided in Section 6.4 of the RI. The overall conclusions are that contaminants in groundwater exceedac-

ceptable risk levels for carcinogenic and noncarcinogenic effects in humans who use the groundwater, and that there is unacceptable ecological risk for aquatic organisms and for semi-aquatic terrestrial organisms (as represented by ospreys, muskrats, and mallard ducks) via the food chain. Most of the human health and ecological risk is related to inorganic compounds such as arsenic, manganese, zinc, lead and iron. Although there is no evidence that inorganics were used at the Massachusetts Military Reservation (MMR), the elevated levels in groundwater were thought to be caused by changes in groundwater chemistry (e.g. low dissolved oxygen) brought about by the biodegradation (and related oxygen consumption) of site-related organic contaminants in the subsurface. Arsenic, manganese, iron and other inorganics are more soluble in groundwater with low oxygen, and are thought to have been solubilized and transported via groundwater to the surface water bodies. The site-related contaminants were limited primarily to organic compounds related to fuels, fuel additives, chlorinated degreasing solvents and deicing compounds. Some of these organics contributed to human health risk of groundwater from some areas of the MMR (Massachusetts Military Reservation), but they were rarely detected in surface water or sediment.

The human health risk assessment estimated the carcinogenic and noncarcinogenic risks for current and future exposure to groundwater from the Southeast Region Groundwater Operable Unit (SERGOU), as well as to sediment and surface water at Ashumet Pond, Johns Pond, the cranberry bog north of Ashumet Pond, and the Quashnet River. Exposures scenarios were based on residential use of groundwater from a hypothetical well, recreational contact with surface water and sediment, and ingestion of fish caught in Ashumet or John's Pond.

The human health risk assessment indicated that the risk of cancer and noncancer effects from current and future exposure to groundwater exceeded the USEPA target range and the MADEP (Massachusetts Department of Environmental Protection) acceptable range. Arsenic in groundwater was the largest contributor to the excess cancer risk in most locations, but site-related organic compounds (chlorinated solvents and benzene) were the major contributor (80%) to cancer risk of groundwater from the southeast MMR.

2.0 EVALUATION OF REMEDIAL INVESTIGATION METHODS

2.1 CONTAMINANT ANALYSIS

The review indicated that the methods for the remedial investigation followed accepted methods. Contaminant analysis was conducted by field methods with an appropriate level of quality assurance or by Contract Laboratory Program methods with the highest level of quality assurance (Level D). Groundwater data were also collected by accepted methods. The risk assessment models used were those identified by the HAZRAP (Hazardous Waste Remedial Actions Program) for use at this site (ASG, 1994). These methods are appropriate for the site and comply with EPA guidance for Superfund remedial investigations.

The nature, occurrence and distribution of contaminants in the SERGOU is well documented in the RI. Organic chemical contaminants have been shown to be migrating in the aquifer, downgradient of the Massachusetts Military Base (MMR). The suspected sources of these contaminants has been extensively researched for the RI.

The RI presents the hypothesis that inorganics have been mobilized in the groundwater due to lowered dissolved oxygen levels in ground water resulting from the degradation of organic materials within the aquifer. This results in increased solubility of naturally occurring inorganics (metals) found in SERGOU soils. The inorganics dissolve into ground water and therefore become more mobile. This theory is supported by work at other sites and by measurement of low oxygen levels in the groundwater at the MMR. Large amounts of organic materials have been added to the groundwater from the prior practice of discharging treated domestic wastewater to the surface soils of the MMR (LeBlanc, 1982). Numerous chemistry studies have shown that many inorganics become increasingly water soluble at lower oxygen concentrations. An example of this phenomenon is the iron-staining which occurs near the outbreak of landfill leachate to the surface. These stained soils have elevated levels of manganese, iron, and sometimes arsenic and other minerals, depending on the composition of the local soil.

2.2 GROUNDWATER MODELS

The ground-water models selected for use by ABB were the U.S. Geological Survey (USGS) Modular Three-Dimensional Finite Difference Groundwater Flow Model (MODFLOW, McDonald and Harbaugh, 1988), and the USGS particle tracking program, MODPATH (Pollock, 1989). These models are well suited for use in hydrogeological environments such as that found in the SERGOU.

Barrier boundaries including constant head and no-flow boundaries define the lateral extents of the MODFLOW domain, while the aquifer can be divided into a finite difference grid using a series of constant water table elevation (head) nodes. The model can be modified to evaluate ground-water flow characteristics with depth by layering a series of grids of an identical area beneath the surficial grid, each representing a portion of the aquifer with differing lateral hydrogeologic properties. Hence, the entire aquifer can be modeled throughout its thickness.

The more complex geologic conditions at depth within the SERGOU aquifer area and the hydrogeologic connections between the ponds and several small streams and bogs in the downgradient areas present an ideal case study for the use of the USGS MODFLOW ground-water flow model.

MODFLOW does not consider particle tracking in its analysis. Contaminant transport was modeled by means of the MODPATH, particle tracking model. This model, however, does not consider the effects of contaminant diffusion, dispersion, sorption or degradation, and thus cannot be used for predicting contaminant concentrations within or the locations of the leading edge of ground-water plumes.

Contaminant retardation within the aquifer was calculated analytically, using standard fate and transport equations and incorporating the appropriate organic chemical constants for each ground-water constituent.

A more detailed analysis of contaminant fate and transport could be achieved by using a mass transport model such as the USGS Method of Characteristics (Konikow and

Briederhoff). This model incorporates several retardation factors, including contaminant diffusion and dispersion. Nevertheless, the models used are adequate to confirm that the semi-volatile organics (SVOCs) released from the MMR in the SERGOU are relatively immobile in the SERGOU aquifer soil system, and that inorganic chemicals in the SERGOU groundwater occur at levels exceeding EPA maximum contaminant levels for drinking water (MCLs) and are migrating with the groundwater plume.

Some evidence was provided that oxygen levels are higher in groundwater wells nearer the ponds, it is reasonable to expect most of the dissolved metals in the plumes to become insoluble prior to entry of the groundwater into the ponds. This may not be the case where groundwater enters areas of naturally low oxygen in sediment, such as the cranberry bogs.

2.3 RISK MODELS

Human Health Risk Models

Risk models were described in the Risk Assessment Handbook (RAH) published by ASG (1994). They are based on equations provided in EPA risk assessment guideline documents (listed in Section 5). Several of the equations were spot-checked and found to be accurate in terms of balancing of units and equivalence to EPA equations.

Risk assessment can be summarized by the equation below:

Risk = Toxicity X Exposure

This equation simply states that risk is a function of both the toxicity of a chemical and its dose. It makes explicit the assumption behind all toxicology and risk assessment that there will be zero toxicity if there is zero exposure, and vice versa.

The exposure dose is calculated by multiplying exposure factors (duration, frequency, amount ingested per event, absorption factor, etc.) by the concentration of contami-

nant in the exposure medium (food, air, water, soil, etc.). This absorbed dose is then divided by the body weight and the period over which the exposure occurs. This exposure is expressed as the weight in milligrams of contaminant per kilogram body weight per day (mg/kg-day).

The toxicity of a chemical is expressed differently for cancer risk than for non-cancer risk. The carcinogenic toxicity is expressed as cancer potency. This potency is quantified as a Cancer Potency Slope (CPS). The CPS is the reciprocal slope of the dose response curve obtained from animal studies with the carcinogen. The CPS is derived by the scientific community and is subject to uncertainty. The most authoritative CPS values are issued by EPA'S Integrated Risk Information System (IRIS). The risk of a carcinogen is expressed as an incremental increased probability over the background risk of cancer. This is sometimes called the Incremental Lifetime Cancer Risk (ICLR).

The toxicity of a chemical can also be expressed for toxic effects other than cancer such as liver damage, developmental effects on the fetus, and so on. This non-cancer toxicity of a chemical is quantified more simply than carcinogens as a Reference Dose (RfD). The RfD is basically the same as a "safe" dose. The RfD is also derived from scientific studies which are subject to uncertainty. The most authoritative RfD values are provided by EPA's IRIS program. Reference doses can be derived for chronic (long-term) or subchronic (short-term) exposure periods. A subchronic RfD would be appropriate for a shorter term exposure scenario (weeks to months) such as construction activity. A chronic RfD would apply to any longer exposures. Reference doses are not generally used to calculate risks of acute exposure (hours or days) to high concentrations of chemicals. These risks are generally covered under occupational safety and health considerations.

There is much uncertainty in extrapolating from laboratory exposures to toxicity in humans. Uncertainties exist in extrapolation from one species to another (white mouse to man), from one exposure route to another (injection in mouse to inhalation in man), and in extrapolation from short-term, high-dose laboratory studies in small, short-lived species such as the mouse to long-term, low-dose exposure in long-lived humans. Other factors include adequacy of the laboratory study and the higher presumed sensitivity of children and elderly humans to chemicals. As a result, the cancer potency and reference doses are adjusted

downward by one or more safety factors (usually tenfold) to account conservatively for these uncertainty factors.

The risk of carcinogenic effects of a chemical is calculated by multiplying the exposure dose by the Cancer Potency Slope. The risk is expressed as a probability. As an example, an increased lifetime cancer risk of one-in-one-million could be expressed as a probability of 0.000001 or as 1 X 10^{-6} or 1E-06. The general lifetime risk of cancer is about 1-in-4 or a probability of 0.25. This could also be expressed as 2.5 X 10^{-1} or 2.5E-01. If this incremental risk of 0.000001 is added to the background 0.25 risk of cancer, the total risk becomes 0.250001, which is not significantly different from the background risk. The acceptable incremental risk for involuntary exposure to hazardous waste is usually considered by regulatory authorities to be somewhere between 1E-04 (1 in 10,000) and 1E-06 (1 in 1 million).

The risk of non-carcinogenic toxic effects is expressed as a Hazard Index or Hazard Quotient, calculated as the quotient of the estimated exposure dose divided by the RfD ("safe" dose). Therefore, any exposure dose higher than the "safe" dose would result in a hazard quotient greater than 1. The acceptable risk of non-carcinogenic effect is generally considered to be a Hazard Quotient of 1.

Ecological Risk Assessment Models

The exposure and risk equations for ecological receptors are similar except that carcinogenic effects are generally not considered. The equivalent "safe" dose for an ecological receptor is often called a "benchmark" concentration. For aquatic organisms, the benchmark concentration is often considered to be the concentration in the water, rather than the internal dose.

Most other ecological exposure scenarios involve modeling the internal dose through direct food and water ingestion or through dermal exposure to soil and water. Calculation of concentrations in food is direct for primary consumers (e.g. soil to earthworm) but indirect for secondary consumers higher up in a food web (e.g. fish to heron, earthworm to

robin). Food web exposure is accomplished by modeling the bioaccumulation at each stage of the food web and comparing the modeled dose with the benchmark derived for that species based on the toxicology literature for similar species.

The Risk Assessment Handbook (ASG, 1994) contains the benchmarks derived for direct and indirect water, soil, and food web exposures for numerous species based on the various life cycles and feeding habits of the organisms. Several of these exposure factors were examined and found to be reasonable. These benchmarks have been derived primarily by scientists at Oak Ridge National Laboratory, rather than EPA. Several exposure calculations were checked against EPA's recent Wildlife Exposure Factors Handbook (EPA, 1993) and found to be equivalent, because they are based on much of the same primary scientific literature on wildlife characteristics.

3.0 EVALUATION OF RESULTS

3.1 EVALUATION OF ARARS

Applicable or Relevant and Appropriate Requirements (ARARs) are the regulatory requirements which should be met as a result of the RI/FS process. ARARs for a Superfund site include Federal and state guidelines, criteria and standards for groundwater, surface water, soil, air and sediment. Although Federal requirements have legal priority over state or local requirements at Federally listed Superfund sites, state and local requirements are often included as ARARs, and the most stringent ARARs usually apply. The ARARs are very important in the RI/FS process because they are considered along with the site-specific risk assessment to determine the cleanup goals. The laws and regulations considered to be ARARs for the SERGOU were listed in Table 3-2 of Volume II of the RI report. The chemical-specific ARARs based on these laws and regulations were listed in Table 4-1 of Volume II of the RI report.

Although the RI report is dated September, 1994, the chemical-specific drinking water standards and guidelines listed as ARARs are from the 1992 Massachusetts Drinking Water Standards. As a result, these drinking water standards in the RI report were spot checked for 20 chemicals against the August, 1994 MADEP list of drinking water standards and guidelines (Anastas, 1994). Most of the concentrations were the same, however 12 chemicals had been changed in status from guidelines to standards. In addition, some chemicals were removed (hexavalent chromium, silver), and the actual concentration limits changed for chlordane (0.0005 to 0.002 mg/l) and sodium (28 to 20 mg/l, guideline). Discussion with MADEP (personal communication, Nicholas Anastas [617 292-5500]) indicate that the updated list will be issued in August, 1995, and that the only change from 1994 will be the guideline for MTBE, a gasoline additive, which does not occur at the MMR. It is concluded that the drinking water ARARs concentrations have not changed significantly since the RI report was published.

The USEPA water quality criteria are also under review, and an update is expected to be issued in August, 1995 (personal communication, Patrick Ogbegor [202 260-6322]).

Massachusetts uses the USEPA water quality criteria as surface water standards. The water quality criteria were spot checked against the list in the RI report (Table 4-1, Volume II), which was based on 1992 USEPA Water Quality Criteria. The criteria for several metals are dependent on water hardness. The criteria in the RI were calculated based on a water hardness of 25 mg/l, assumed to be the hardness of Ashumet Pond. A footnote in Table 6-14 of Volume II of the RI indicates that this was an assumption, not based on site-specific data. These calculations were checked, and the criteria were checked against the most recent values. Criteria for most of the metals were correct and up to date. However, criteria for two metals were miscalculated. The acute criteria for copper should have been 4.8 µg/l, rather than 58 µg/l. The chronic criteria for cadmium should have been 0.4 µg/l, rather than 40 µg/l.

It was noticed that there were no ARARs for sediment presented in the RI. Massachusetts is currently preparing guidance for environmental risk characterization which includes the use of NOAA (National Oceanographic and Atmospheric Administration) sediment screening concentrations for preliminary assessment of ecological risk. These sediment guidelines are expressed as ERLs (Effects Range-Low) and ERMs (Effects Range-Median) by Long and Morgan (1990). The ERL reflects the concentration below which effects are unlikely. The ERM reflects the concentration above which effects are likely. The ERL and ERM values were derived from a review of the scientific literature which examined the effect and no effect concentrations obtained in a variety of studies. Most of these studies obtained simultaneous measurements of sediment contaminants and biota in the marine environment.

The ecological risk assessment did not use ERL and ERM values as benchmarks to assess risk to aquatic and semi-aquatic wildlife. Rather, the risks of sediment were evaluated by comparison with benchmarks derived by estimating the concentration of chemical in the pore water within the sediment. This estimate was made for organic and inorganic compounds using generally accepted published techniques which model the partitioning of metals and organics between sediment and water.

The estimated pore water concentration was compared with EPA Water Quality Criteria or other toxicity data to assess whether the pore water concentration was toxic. This method has been used by EPA to derive draft Sediment Quality Criteria for several non-polar

organic compounds. There is much current scientific uncertainty about this approach for metals and organics in sediment because of the large number of factors which are known to influence partitioning, such as organic carbon, sulfide, grain size, mineral content, oxidation reduction state and others.

3.2 CONTAMINANT DATA

The usability of data was evaluated and found to be generally usable for risk assessment. Contract laboratory program (CLP) detection limits were generally met, and the exposure point concentrations calculated from the data were adequate to represent conditions at the various sites. The human and ecological risks were calculated based on both the maximum and average chemical concentrations. As a result, the assessment provided very conservative risk estimates.

Some ecological benchmark concentrations are lower than the required CLP detection limit. The detection limit required under the CLP program is generally the detection limit that is routinely achievable in a good laboratories using detailed, but routine methods of extraction and analysis. Soil, water, sediments and tissues often contain materials which increase the detection limit because they interfere with the extraction or analysis of the test chemical. Non-routine extraction, sample cleanup and analytical procedures may be required to reach lower detection limits.

It is impossible to know whether a benchmark is exceeded for chemicals with detection limits higher than the benchmark. For instance, the routinely required detection limit for PCBs in surface water is about 10 µg/l. The EPA water quality criteria for PCB is 0.014 µg/l. The discrepancy between the detection limit and benchmark for chemical such as PCBs is well known by ecological risk assessors. If such a chemical is known to occur at a site, it will be important to use special techniques to achieve lower detection limits. However, in most cases, including the MMR ecological risk assessment, this problem is not significant. As mentioned previously in the introduction, the ecological risk at MMR is driven primarily by food web ingestion of inorganics such as arsenic and manganese. These metals can be detected at very low concentrations in most media. As a result, there is greater confidence that

the food web modeling is based on accurate measurements of these chemicals in water, soil and sediment. Since the detection limit is higher than the benchmark, it is often impossible to know whether the benchmark is exceeded in water or sediment. The Contract Required Detection Limit (CRDL) in soil/sediment and surface water is 2 ppm for arsenic and 3 ppm for manganese. A review of the sediment and soil data in Appendix Q, Volume V of the RI indicate that the CRDL was met in all but a few analyses for these metals.

With regard to the groundwater modeling, the RI presents a detailed summary of the concentrations of various chemical constituents detected in monitoring wells installed in the SERGOU. However, the contaminant data presented as model input parameters in the RI appears to be limited only by the inability to effectively quantify releases of chemicals from the MMR and within the SERGOU. Estimates of the concentrations or volumes of contaminant releases are not presented.

The RI does not present any details or "hard evidence" that petroleum-based carriers for application of pesticides/herbicides were used in the bogs. The RI assumes that bogs are a potential non-point source of petroleum hydrocarbon (PHC) contamination of the SERGOU. If no PHC carriers for pesticides/herbicides were used in the bogs, the model likely places several points of application of PHC contaminants too far downgradient within the model's domain.

The RI fails to recognize that 1,1,1-trichloroethane (TCA) can degrade to 1,1,-dichloroethylene (DCE) - see RI § 5.0, p.5-3. This may result in failure to accurately trace pathways of chlorinated solvent contamination to their respective source(s).

3.3 GROUNDWATER MODELING RESULTS

A computer simulation of a generic pond/ground water environment was simulated as part of the RI. Hydrologic parameters unique to Johns Pond were used in this simulation. The RI shows that the two ponds differ hydrologically, with respect to their depths and uniformity of basin shape.

A computer simulation of Ashumet Pond was not performed to evaluate the unique hydrologic characteristics of this basin. Eight rounds of seasonal water level measurements were collected in monitoring wells and piezometers from April 1990 to April 1994. These measurements were collected to provide data to define typical annual high and low ground water levels.

No water level data was collected from wells or piezometers during the drought period from mid-1990 through 1991. This data would have been useful for extrapolation of long-term contaminant transport trends under extremes of ground water conditions.

The RI presents an estimate of input from domestic septic system discharge into the mass balance equation for Johns Pond. Upgradient septic discharges were quantified in the RI for input into the water budget analysis. Given that many of the residences within the Briarwood development are likely seasonal, ground water loading values from upgradient, domestic septic systems may be slightly overestimated.

Detailed, high-resolution bathymetric data was collected from both ponds (Ashumet and Johns) in October 1993. The results of the bathymetry surveys identified six deep "holes" which were located and mapped on each of the northern and southern ends of both ponds (4 total) and two near the center of Johns Pond. The Ashumet and Johns Ponds Task Force (AJPTF) sampled sediments at six locations in both ponds in August 1993. According to the RI, AJPTF sampling locations included the deep "holes" in each pond.

The AJPTF collected sediment samples from deep holes in each pond, prior to the collection of detailed bathymetric mapping of the ponds. If the locations and depths of these "holes" were not yet identified in detail by August 1993, sediment samples collected from these areas prior to October 1993 may not be representative of the deepest sediment layers from the ponds.

It is unclear in the RI if the six sediment samples collected by the AJPTF were taken from each of the six deep "holes" identified in the ponds, or if some, but not all of the deep holes were sampled in addition to sampling at both ends of the ponds (not in holes).

The MODFLOW-predicted inflow value for Ashumet Pond was 339,350 cf/day, compared with calculated values presented by K-V Associates, Inc. and IEP, Inc. (1987) of 303,334 cf/day (11% difference).An inflow value of 354,067 cf/day (3.55E06 m^3/yr) for Ashumet Pond has been calculated by Kerfoot (1990). This represents a more favorable calculated value for comparison of the modeled result, being only 4.3% higher than the predicted (modeled) inflow.

The water budget analysis figure for April 1993 is not presented in the RI report. Figure 2-12 presents the areas used in water budget calculations for December 1993 data only. No data (ground water contours) are shown for the areas northwest, west and southwest of Ashumet Pond in Figure 3-8 of the RI (map date December 1993). Data from these areas are shown on the April 1994 ground water contour map (Figure 3-9), however.

3.4 ECOLOGICAL RISK ASSESSMENT

The usability of data for calculating exposure point concentrations and average media concentrations was evaluated by comparing the Contract Required Detection Limits (CRDLs) with soil, sediment and surface water data from the Quashnet River, Ashumet Pond and John's Pond (Appendix Q, Volume V of RI). This review was limited to all of the values for manganese and arsenic and spot-checks on the other metals and organics. All of the arsenic analyses, and all but a few of the manganese analyses, achieved CRDLs. The review found that CRDLs were not achieved for many of the lead and zinc analyses, as well as most of the semivolatile organic compounds. The achieved detection limits for the latter compounds were reasonably close to the CRDLs (usually same order of magnitude). Further review indicated that compounds were generally detected with reasonable accuracy if they occurred frequently in the sediment or water. Additional detections would have resulted in higher risk estimates but would not have changed the basic conclusions of the risk assessment that the risks were unacceptable to semi-aquatic wildlife.

3.5 HUMAN HEALTH RISK ASSESSMENT

The useability of contaminant data was evaluated by comparing the CRDLs with the contaminant data for groundwater, the major source of human health risk in the SERGOU. A brief review of the analyses of groundwater indicated that CRDLs were generally achieved for inorganics and organics.

The calculation of Exposure Point Concentrations (EPCs) was done appropriately. The EPCs used for calculation of risk were both the maximum and average concentrations for the well water samples for each area under consideration. The use of maximum concentrations provide a conservative estimate of risk.

The appropriateness of the selection of Contaminants of Concern (COCs) for the human health risk assessment was assessed by reviewing Table 6-2 of Volume II of the RI. This table shows the detection frequency, the minimum, maximum, and mean concentration, and the basis for excluding a particular contaminant from the risk assessment. Contaminants were excluded from the assessment if: 1) The maximum concentration was less than the maximum site background concentration, 2) The maximum concentration was less than the risk-based screening concentration (Hazard Equivalent Concentration, or HECs), 3) The detection frequency was less than 5%, and 4) The analyte is an essential human nutrient not considered to be hazardous. Review of the chemical selection procedure indicated that COCs were selected appropriately.

As described previously, calculation of human health risk requires the use of Cancer Potency Slope (CPS) values for cancer risk and the Reference Dose (RfD) for non-cancer risk. The most current approved toxicity factors are provided by EPA's IRIS program. The CPCs and RfDs for the most important risk-contributing chemicals presented in the RI and the Risk Assessment Handbook (ASG, 1994) were reviewed against the most current available compendium of IRIS values (Smith, 1995). The CPC and RfD values appeared to be current.

Human health risk assessment involves several components, including 1) exposure assessment, 2) toxicity assessment, 3) risk characterization, and 4) uncertainty evaluation. The

exposure assessment includes identification of potential exposure pathways, selection of contaminants of concern (COC) and estimation of exposure point concentrations (EPCs). The toxicity assessment includes identification of the toxicity parameters for each of the selected contaminants of concern. The risk characterization includes the calculation of the risks of carcinogenic and noncarcinogenic effects. The uncertainty analysis includes an assessment of the uncertainties involved in the risk characterization estimate.

Human exposure pathways selected in the RI included current and future exposure to groundwater as well as sediment and surface water at Ashumet Pond, Johns Pond, the cranberry bog north of Ashumet Pond, and the Quashnet River. Exposures were based on residential use of groundwater from a hypothetical well, recreational contact with surface water and sediment, and ingestion of fish caught in Ashumet or Johns Pond. Since the RI was addressed only to the impacts of groundwater in the SERGOU, there was no assessment of surface soil contamination on the site. Presumably, the risk of exposure to soils during construction or future residential use of the MMR will be addressed at another time.

The exposure assumptions utilized for the selected human exposure pathways are summarized in Tables 1, 2 and 3 of Appendix N-1 of the RI. These exposure assumptions are based on general USEPA or HAZRAP guidance, rather than site-specific measurements or estimates. The exposure assumptions for each of these scenarios will be discussed below.

Swimmers

The exposure assumptions for recreational swimmers are presented in Table 1 of Appendix N-1 of the RI. Exposure assumptions include incidental ingestion of 100 mg/day of sediment, incidental ingestion of 130 ml/day of surface water, dermal exposure of the whole surface area of the body to water, dermal exposure of the surface area of the legs to sediment and a swimming frequency of 7 days per year for 30 years. The incidental ingestion of water is based on 50 ml/hour for 2.6 hours per day swimming. Assumptions in this scenario include adult body weight and skin surface area and the assumption that all of the swimming related exposure occurs at the site, rather than at other locations.

This exposure scenario does not assess the higher exposure that is likely to occur among children living near Johns Pond and Ashumet Pond. It is likely that these children swim daily during the summer for periods longer than 2.6 hours per day. Swimming daily for three months (June-August) would result in an exposure frequency of 84 days/year rather than the assumed 7 days/year. This factor would increase the exposure about 10-fold (10X). A more realistic swimming period may be about 5 hours, or a doubling of the 2.6 hour assumed swimming period. This would double the water ingestion rate to 260 ml/day (2X). The surface area for the whole body and legs of a child aged 9-12 would be about half that of an adult, therefore the dermal dose per unit skin area would be about half (0.5X). The exposure duration for a 15 year old child should be adjusted from 30 years to 15 years which would decrease exposure by about half (0.5X). The body weight would be about half that of an adult, therefore the dose per unit body weight would be doubled (2X). These factors combined would increase the calculated exposure by a factor of about 10 (10 X 2 X 0.5 X 0.5 X 2). Since risk is a function of exposure, this would result in a risk estimate about one order of magnitude higher than estimated in the RI. The potential impact of this is minor because the risks of swimming were considered to be close to the acceptable level. Since there are many conservative assumptions already inherent in the risk calculations it is probable that this does not have a significant effect on the risk levels.

Recreational Fish Consumption

The exposure assumptions for fish consumption by recreational users of surface water are presented in Table 2 of Appendix N-1 of the RI. Exposure assumptions include consumption of two 8-ounce servings per week of fish caught from the site. This may be a reasonable estimate for a typical adult recreational user of the ponds, but may underestimate the exposure of children or adults who catch and consume fish from the ponds more than twice per week. The meal size assumption represents the upper 95th percentile of fin fish consumption. The assumed meal frequency is an upper bound estimate: the average is 48 meals/year. A more site-specific estimate of fish consumption would involve surveying the people who actually fish on the ponds or river. The exposure assumptions for fish consumption in the RI are considered to be reasonable in the absence of more site-specific information.

Residential Drinking Water

The exposure assumptions for residential use of drinking water are presented in Table 3 of Appendix N-1 or the RI. Exposure assumptions include daily 12-minute showers, ingestion of 2 liters per day, and adult body weight and surface area. Exposure to children is likely to be equal or lower because they will drink less, shower less frequently, and have a lower exposure duration (as children). As a result, the exposure assumptions are considered reasonable.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 GROUNDWATER MODELING

The review of groundwater modeling has focused on an evaluation of RI methods for contaminant analysis and ground water models; an evaluation of model assumptions, input parameters and results; and data gaps in the model output. The RI and supporting documents were examined for anomalies in the data presented and inconsistencies in the model results. The RI presents a concise summary of aquifer characteristics in the SERGOU, and details a fairly diligent analysis of ground water flow and contaminant fate and transport.

In some aspects, particularly the input parameters for chemical contaminant source levels, the model may underestimate actual contaminant release quantities and concentrations into the SERGOU and areas downgradient from the MMR. Given the lack of detailed data regarding contaminant releases, the assumptions presented in the model should suffice as "best estimates" for the RI analysis.

With regard to the model's potential overestimation of flow input parameters, particularly in the areas upgradient to Ashumet Pond, we find that the output values predicted by the model for total flow input to Ashumet Pond match closely with recently calculated data, by others. Any potential overestimation of flow inputs can be considered minor.

It is recommended that certain data gaps be addressed and clarified for completeness. These would include:

1) Presentation in the RI of a water budget analysis figure for April 1993.

2) Clarification in the RI of why the six sediment samples collected by the AJPTF were taken from the deep "holes" in each pond prior to the dates during which the holes were first mapped in detail.

3) Addition of ground water contours in the areas northwest, west and southwest of Ashumet Pond to Figure 3-8 of the RI.

4.2 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment concludes that some contaminants, primarily manganese, arsenic and zinc, may pose a significant risk to aquatic organisms and wildlife consumers of aquatic organisms and vegetation. The inorganics mobilized in SERGOU groundwater by the decay of organic materials from MMRA and consequent oxygen depletion has undoubtedly contributed to the level of inorganics found in pond, river and bog sediments and surface water. However, SERGOU is not the only source of these inorganics, which occur naturally in most surface waters and sediments. Based on analyses in groundwater from wells near John's Pond, the RI states that dissolved oxygen concentrations increase and inorganic concentrations decrease before groundwater discharges to the pond.

Although ecological risk assessment is much newer and less standardized than human health risk assessment, the ecological risk assessment was conducted by generally accepted scientific methods. The modelled concentrations in the representative food organisms and semi-aquatic consumers (muskrat, mallard, osprey) were compared with no-effect doses derived from the scientific literature, as compiled in the Risk Assessment Handbook (ASG, 1994).

This review concurs with the overall ecological risk assessment conclusion that there may be a significant risk to wildlife from the inorganics, which are elevated in part due to SERGOU discharge to the ponds. Since multiple conservative assumptions were made for each step of the risk assessment, it is probable that the actual risks are lower than estimated in the risk assessment. An example of this conservativeness is presented in the RI. The food web model for manganese was based on food consumption assumptions and bioaccumulation assumption derived from the scientific literature. As an example, the modeled concentrations of manganese in fish in Ashumet Pond and John's Pond were 120,000 and 8.960 mg/kg, respectively. The actual measured concentration of manganese in the whole bodies of fish samples was 15.1 and 54.8 mg/kg in Ashumet and John's Pond, respectively (ABB 1994, volume 1, p.6-48). The risks to osprey consuming fish was estimated based on the modeled fish concentrations. As a result, the risk estimate to osprey may be overestimated by two to four orders of magnitude.

Multiple conservative assumptions are made in human health risk assessment, in part because it is unethical to conduct experiments on humans to determine the actual toxicity of chemicals found at a hazardous waste site. Some human health risk assessments at particularly contaminated sites (e.g. PCBs at New Bedford Harbor) can benefit from biomonitoring of residents to determine if there are elevated levels of contaminants in blood or urine in people who are more exposed than others. Similarly, epidemiological studies can be conducted for discerning health patterns. In contrast to human health risk assessment, ecological risk assessment may be able to reduce some of the uncertainty by conducting measurements and experiments in the potentially impacted area.

Since the results of this ecological risk assessment indicate potentially significant impacts on aquatic benthic organisms and semi-aquatic wildlife, it is recommended that several field studies be conducted to reduce the uncertainty associated with the risk estimates. The data used for the ecological risk assessment was limited to chemical analysis of sediment, surface water and fish. The analysis of fish tissue concentrations was not used in the assessment. Similarly there was no measurement of the abundance and diversity of benthic organisms in the area of concern to see if there was an actual impact on the benthic community.

The greatest uncertainty in the ecological risk assessment is direct impact to benthic organisms and food web transfer to muskrats, ducks and osprey. To reduce this uncertainty the following steps are recommended:

1) Conduct additional analyses of fish tissue caught from both ponds to determine a more accurate average and maximum level of arsenic, manganese and other inorganic constituents. Since ospreys consume whole fish, it is important to measure the concentration in whole fish.

2) Conduct a focused risk assessment using the same methods as used in the RI to estimate the risk to osprey, except use actual measurements of chemicals in fish.

3) Conduct chemical analysis for inorganics in several representative samples of vegetation consumed by ducks and muskrat. Vegetation samples should be collected in areas of SERGOU groundwater discharge to the ponds.

4) Conduct a focused risk assessment using the same methods as used in the RI to estimate the risk to ducks and muskrat, except use actual chemical measurements.

5) Conduct a focused assessment of impact to benthic organisms. This could include standard sediment bioassays with midges and amphipods using sediment taken from the area of concern and a similar control area. If conducted, it would be important to measure the concentration of contaminants in the experimental and control sediment samples along with other sediment characteristics (grain size, organic carbon, sulfide, etc.) to aid in the interpretation of results. This focused assessment would ideally include a quantitative study on the diversity of species and numbers of each species from the area of concern, and comparison with a reference or control area of comparable habitat.

6) Although it is controversial to kill ducks and muskrat for analysis of tissue concentrations, it is possible that local hunters and trappers may be willing to contribute samples of tissue, fur or feathers for chemical analysis. The levels of many metals in hair and feathers has been shown to reflect the exposure of the animal. In any event, actual measurement of the chemicals of concern will greatly reduce the uncertainty surrounding the current unacceptable ecological risk.

4.3 HUMAN HEALTH RISK

The human health risk assessment concludes that contaminants in SERGOU groundwater pose an unacceptable health risk to users of that groundwater. Most of the risk is related to inorganics such as arsenic and manganese which have been dissolved into the groundwater as a result of oxygen depletion in the groundwater caused by decay of organic material and organic contaminants from the MMR. This review concurs with this assessment.

The human health risk assessment also examined the risks of contact with surface water or sediment in the areas where SERGOU groundwater discharges. The assessment did not result in cancer risk above the EPA target range or DEP's acceptable level. The assessment also found that noncancer risk for contact with sediment or surface water did not exceed a hazard quotient of 1, with the exception of a hazard quotient of 2 for ingestion of surface water at Ashumet Pond, due to manganese in surface water.

This risk was calculated on the basis of an oral Reference Dose of 0.005 mg/kg/day, approved by EPA. Recent communication with a risk assessor at EPA-Boston (Margaret McDonough, 617 573-5714) indicates that the Reference Dose for manganese will be withdrawn because reevaluation of the toxicity information indicates that manganese is less toxic than previously thought. The new oral Reference Dose will be 0.14 mg/kg/day which is 28 times higher. If this new reference dose were to be used, the hazard quotient for ingestion of Ashumet Pond surface water would be less than 1. As a result, it is concluded that the risk of drinking Ashumet Pond water during swimming is acceptable.

The human health risk of fish consumption was also estimated based on actual analysis of fish from John's Pond and Ashumet Pond. The carcinogenic risk associated with fish from Ashumet Pond was estimated to be 8×10^{-4} (8 in 10,000), which is higher than EPA's target range of 1×10^{-4} to 1×10^{-6} and DEP's acceptable level of 1×10^{-5}. This estimate was based on concentration of arsenic in the one fish in which it could be detected. This level of arsenic was associated with a hazard quotient of 3. Arsenic was not detected in fish from John's Pond.

The risk assessment was conducted according to conservative methods, using standard exposure assumptions and current toxicity parameters. Although a few errors were found, these do not have any impact on the overall conclusion that groundwater has an unacceptable health risk. The conservative methods used in this risk assessment make it probable that the actual risks are lower, somewhere between zero risk and the estimated risk. The large uncertainty in the risk estimates is a function of the multiplication of numerous conservative assumptions in the exposure and risk equations.

Since the greatest concern of local residents is potential risk from exposure to surface water, sediments and fish caught in John's Pond and Ashumet Pond, the following steps are recommended to reduce uncertainty:

1) Conduct additional analyses of fish tissue caught from both ponds to determine a more accurate average and maximum level of arsenic, manganese and other inorganic constituents.

2) Conduct a site-specific analysis or survey of fish consumption patterns around the ponds to refine the estimate of how much fish is being eaten by children and adults.

3) Conduct a focused and limited risk assessment of fish consumption using site-specific consumption data and results from fish tissue analysis.

4) Repeat the analysis of surface water of Ashumet Pond to confirm whether manganese is elevated above acceptable risk levels.

5) Conduct a site-specific analysis or survey of swimming patterns by children and adults who reside or vacation around the ponds.

6) If manganese is confirmed to be elevated in pond water, conduct a focused and limited risk assessment with site-specific swimming data.

5.0 CONCLUSIONS

The conclusions of this review were in substantial agreement with the conclusions of the ABB (1994) report. The main conclusions and associated recommendations are presented below:

1) Primary contaminants associated with the site (fuels, additives, deicers, solvents) are generally not detected in surface water off the site. However, inorganic minerals such as iron, zinc, manganese, and arsenic are elevated in groundwater due to biodegradation of the primary contaminants. This biodegradation causes oxygen depletion and solubilization of naturally occurring minerals. These elevated concentrations of dissolved minerals are being transported to the surface waters.

2) Since contaminants in groundwater in the SERGOU area exceed EPA and Massachusetts standards and guidelines, it is unsafe for people to use groundwater from wells in the SERGOU area. This conclusion is supported by the results of the risk assessment.

3) Swimming in Ashumet Pond and John's Pond is safe, even if some water is accidentally ingested during swimming. Dermal contact with water and sediments should not pose a significant health risk.

4) Based on the results of three water samples, manganese is higher than normal in Ashumet Pond surface water. This is probably caused by the elevated manganese in the Ashumet Valley plume, which enters Ashumet Pond at Fishermen's Cove. As shown by the presence of black material on rocks in this area, most of this manganese is precipitated when it reaches the pond. Skin contact and incidental ingestion of Ashumet Pond water during swimming should not have a significant health risk. However, use of Ashumet Pond as a source of drinking water is not recommended at this time. Additional water samples should be analyzed and the results evaluated in light of the latest EPA toxicity information for manganese. EPA is reevaluating the toxicity for manganese since the available research indicates that manganese may be less toxic than previously thought. As a result, it is expected that further analysis will confirm that manganese does not have a significant health risk in Ashumet Pond.

5) Regular consumption of fish from Ashumet Pond may be unsafe, based on the level of arsenic measured in the one fish (out of four fish analyzed) in which it could be detected. Occasionally eating fish from Ashumet Pond is probably safe. Additional fish should be analyzed and the results analyzed to determine a more accurate level of arsenic in fish. The source of arsenic is unknown but is probably related to the SERGOU plume, which contains elevated arsenic levels.

6) It is safe to eat fish from John's Pond. Neither arsenic nor other toxic chemicals were detected at significant concentrations in fish from this pond.

7) The measured concentrations of inorganics in surface water were below toxic levels for aquatic organisms. Toxicity modeling of inorganics in sediments indicated that toxic effects may be occurring in bottom-dwelling aquatic organisms in both ponds. This modeling was based on calculation (not measurement) of inorganics in sediment pore water. In the absence of further studies (such as bioassays or pore water measurement), it must be concluded that these sediments are probably toxic to aquatic organisms.

8) Some of the inorganics transported to the pond surface water and sediment may pose an unacceptable ecological risk to wildlife such as osprey, mallard ducks and muskrat. This risk is based on conservative modeling of the transfer of these inorganics via food (fish and vegetation) to these organisms. However, a comparison of modeled versus actual concentrations of manganese measured in pond fish suggests that the food chain model may overestimate risk by two to four orders of magnitude (by a factor of hundreds to tens of thousands). Additional analysis of fish tissues is needed to obtain a more realistic estimate of ecological risk via the pond food chain.

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